Environmental Monitors on Lobster Traps Phase VII: Validating Ocean Models

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Project Objective and scientific hypothesis:

As noted in our 2011 Annual Report and original proposal for this work, our primary objective is to engage fishermen, students, and numerical modelers in a joint effort to validate simulations of New England's coastal current. The traditional means of ground truthing ocean circulation models typically involves deploying a few moorings at selected locations within the domain but this leaves much of the complexity of the flow field unresolved. We choose to devise a system where low-cost instrumentation can be built and deployed by students and fishermen, respectively, at more locations. While traditional scientific moorings cost many tens of thousands of dollars to deploy and maintain, our observations cost at least an order of magnitude less, cover a much larger portion of the study area, and involve different sectors of the society beyond the academic scientists.

Given the topographic complexity off our coast, there is considerable spatial variability in the coastal currents which are affected by these bathymetric variations. There are evidently small areas of convergence and divergence that results in varying degrees of retention and dispersion of water parcels. Now that our circulation models have reduced their grid cells down to less than a kilometer resolution, they are capable of depicting some of these small scale features.

One example of a potentially important small scale feature is an area of relatively stagnant flow at the mouth of Buzzards Bay. While the semi-diurnal tides are fairly strong in this area, the residual means are near zero in contrast to a strong westward coastal current just offshore. Since lobstermen and scientist working together the last few years have found a higher concentration of egging female lobsters in this region, there is some discussion of the consequences. When lobsters release their eggs from the bottom, are they more likely to be caught in the westward coastal current or do they quickly ascend to the surface and then get affected up the bay in a wind-driven northeastward surface current. Given the dozens our drifters that have been deployed in this area in the last few years, we are beginning to understand the details of the mean flow as well as the temporal variability of small scale circulation patterns such as this feature south of Buzzards Bay.

Methods and work plan:

As proposed, we expanded on the eMOLT phases that had worked well in the recent past (drifters, current meters). Ten drifters were to be constructed by students and delivered to lobstermen to deploy. Fifty-bottom current meters were to be built and delivered to lobstermen along the coast. Data from the drifters, in particular, was to be shared with the High-Frequency Radar personnel at multiple labs so they could validate the surface currents derived from these systems. Salinity sensors were to be deployed by a few lobstermen in an attempt to correct for the difficulties experienced in eMOLT phase II. Web-based displays of all of the above were to be built and lobstermen were to be asked to comment on these pages.

As the main components of our outreach effort, we had proposed both a day-long eMOLT event at the Maine Fishermen Forum as well as presentations to students.

Work completed from mid-2011 to now:

In the past several months, subsequent to submitting our annual report in July 2011, we have continued our quest to validate models on a number of fronts. The most important progress has been in converting our code from MATLAB to the open source PYTHON. This has allowed us to install the routines on multiple machines and to share the code with others.

We have initiated a Woods Hole Python Users Group that meets on a weekly basis to discuss this transition and to share ideas on how to conduct it. It has resulted in a repository of code posted at: http://massimo-timecapsule.whoi.edu/whython We have made these modules now available to the public so that anyone can conduct our model-data comparisons. Given that they utilize a non-commercial software, these utilities could be downloaded and used by teachers and students, for example, who may not have the resources for Matlab and other commercial software.

Now that the tools have been developed (primarily PYTHON routines), we have begun to conduct more quantitative analysis of the models performance. We often examine the model output from “hindcast” runs. These are simulations of past periods. It is essential to test the model's hindcast performance prior to its forecast performance as these simulations have the advantage of “data assimilation”. If a model can not provide reliable hindcast, it can not be expected to provide a reliable forecast.

Given the Massachusetts Ocean Partnership (MOP) funding the FVCOM modeling group, a complete hindcast of our coastal waters from 1978 to present is underway. As of this writing 1978 through 1995 simulations are available for each hour. This model output will be particularly valuable to fisheries biologist, for example, who are trying to understand the interannual variations in recruitment of commercially-important ground fish on Georges Bank and elsewhere. We can now provide them with the potential transport paths of eggs and larvae for different years. In Figure 1, for example, we show the different trajectory of particles released at the same location on October 15th in different years. We conduct other experiments to examine the flow at different depths as illustrated in Figure 2.

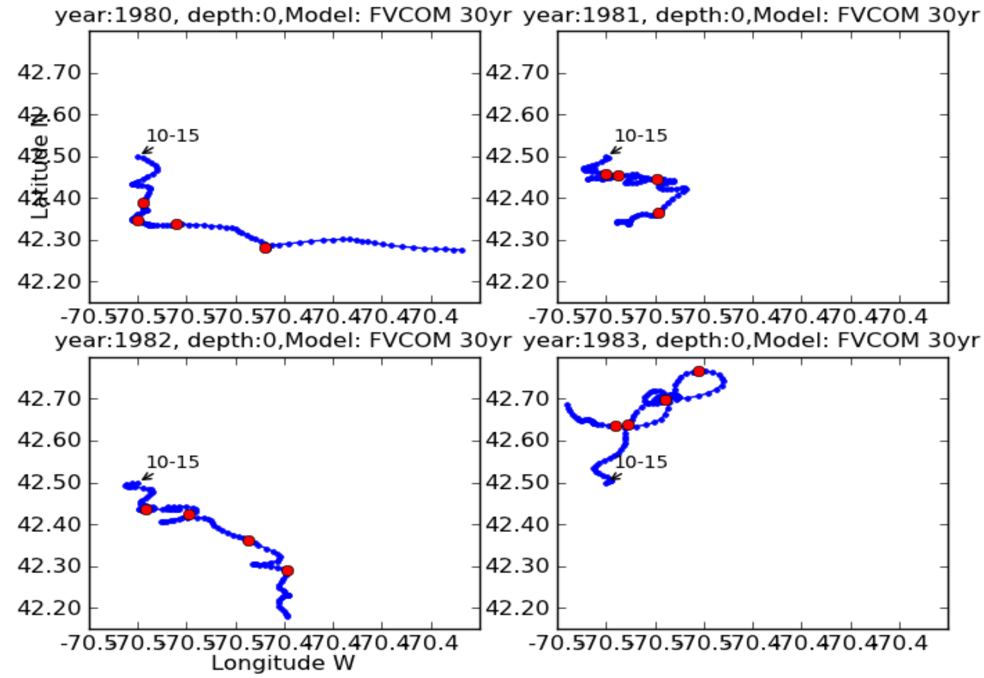


Figure 1. Model trajectories and daily positions (red dots) of numerical drifters deployed at the same location in different years.

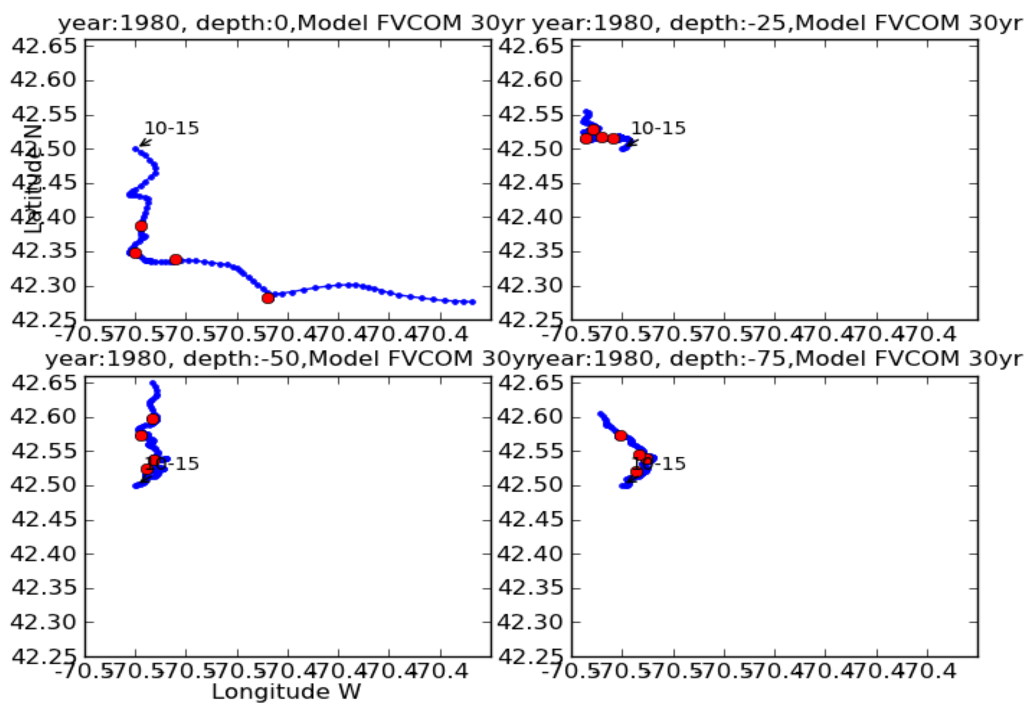


Figure 2. Model trajectories beginning at the same time but at different depths.

In the last few months, we have started comparing the model particle trajectories with actual drifter tracks. We have used the SCOPEX drifter from the late 1980's and calculated, for example, the “separation distance” between model and observed restarting the comparisons every two days. The result for a particular drifter (Figure 3 below) show the affect of the model's tidal excursions that were not resolved in the rough drifter fixes. This same comparison has been conducted for dozens of drifters which has generated a large dataset as shown in Figure 4 below. The results vary from a few kilometers to tens of kilometers per day.

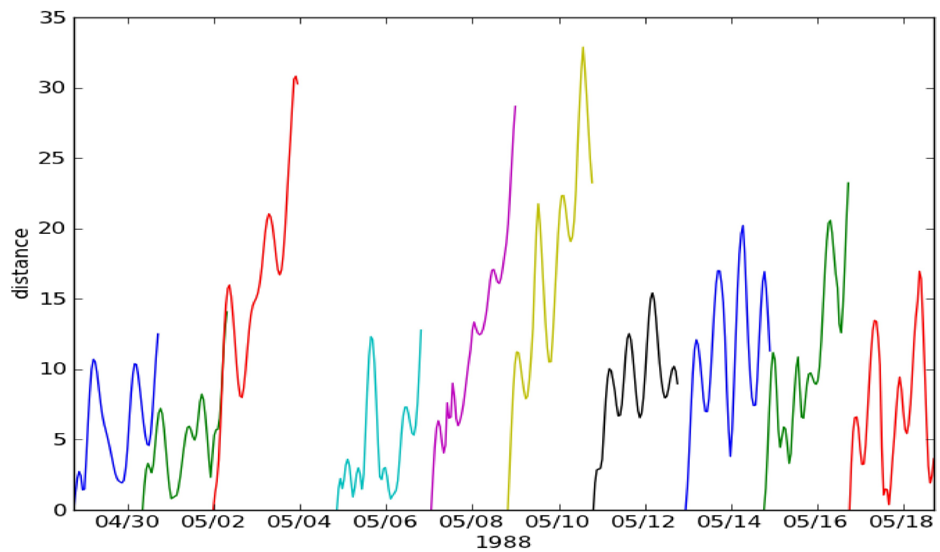


Figure 3. Separation distance of modeled vs observed drifter.

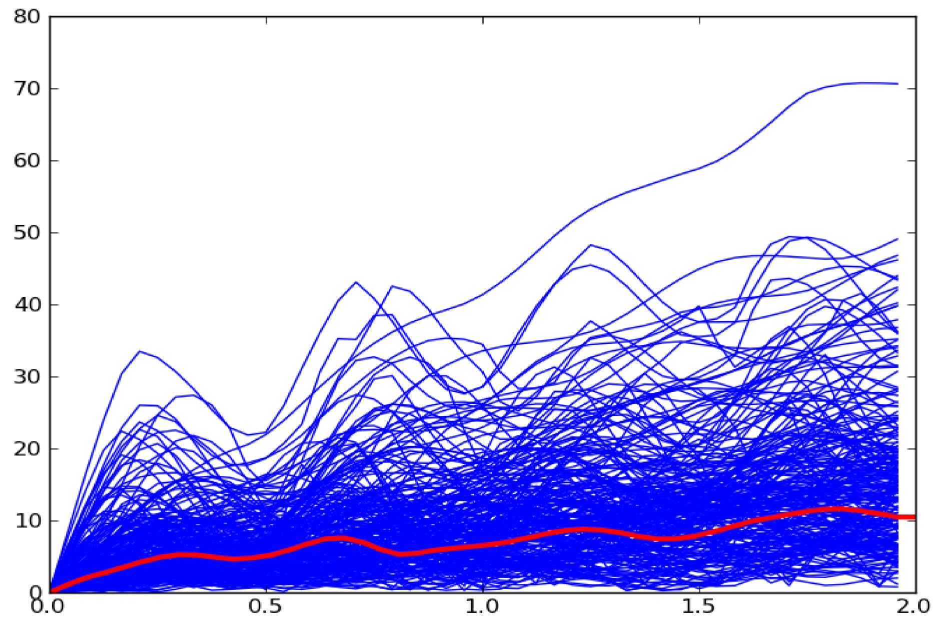


Figure 4. Model vs oserved drifter separation in kilometers (y-axis) vs time in days (x-axis) for late 1980's hindcasts.

As noted in last year's annual report, given some of the drifters funded through this Phase VII project, we have been able to build a close collaboration with the Zephyr Marine Education Foundation in Woods Hole. Beginning in April and throughout this past summer, we conducted bi-weekly drifter deployments in local waters when groups of primarily high school students go on-board, witness the deployments, and subsequently follow the path of the drifters on a customized googlemap on-line. From this project alone, approximately 50000 kilometers of ocean has been logged in Southern New England Waters and beyond. As these drifters approach other shores, they are picked up by students elsewhere. URI students, for example, have been involved with a few recoveries and have made some deployments themselves. A total of 14 drifters were deployed by URI students in 2011 and some of them are still transmitting today from the tail of the Grand Banks.

Another drifter-building workshop was held in August 2011 in Monterey California. Leveraging NSF-funding to the “Marine Advanced Technology Education” group, several colleges will be able to send marine science teachers to this 3-day event and allow them to return with a ready-to-deploy drifter. The drifter construction manual we have developed over the last few years was followed and teachers were able to have their students build more drifters. The primary focus here, however, is not to maximize the drifters deployed but to get the most out of the drifter data that is generated. Much of the teaching is associated with the downloading, processing, and visualizing of drifter tracks.

Students learn how to plot the tracks and overlay other information such as the wind fields and the numerical model fields.

The bottom current meter project has succeeded thus far. After our initial deployment on 11 lobster traps in the fall of 2008, another set of 27 were deployed and recovered in fall of 2010. Given these encouraging pilot projects, we then sent out units to 50 different lobstermen in 2011. These were out for the entire fishing season so that we have got most of them back at the time of this writing.

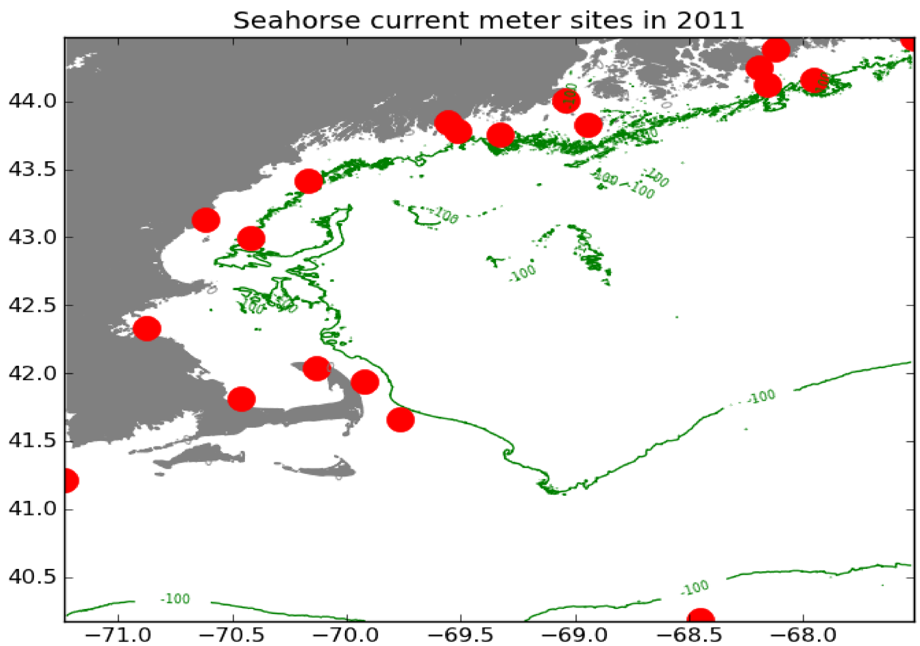


Figure 5. Locations of 2011 SeaHorse current meters (red dots) with data available at the time of this writing and the 100m isobath (green lines)

The locations are depicted in Figure 5 are those for the 2011 deployment. An example of the type of data returned is plotted in Figure 6 below.

Finally, the most recent eMOLT-related work in is in deploying digital-cameras on lobster traps. Working in collaboration with ocean engineers at Woods Hole Oceanographic Institute, we prepared several cameras and sent them out to lobstermen. With the help of NOAA divers, we have tested their waterproofed housings and the light limitations in water depths up to 10 meters off the dock and were happy to find they also work in the various environments that the fishermen work. While these cameras help us document the performance of our instrumentation (drogued drifters and tilt current meters), the 20+ plus lobstermen who responded to our email are obviously interested in monitoring the activity of their trap so that the collaborative project is a win-win situation. While these cameras have battery power limited to 4 hours when a frame is stored each minitue, our next step is to find a camera system with true time-lapse functionality so we may get time series over days or weeks. Lobstermen and scientist alike may obtain a better understanding of the catch dynamics. A example photo obtained is provided below.

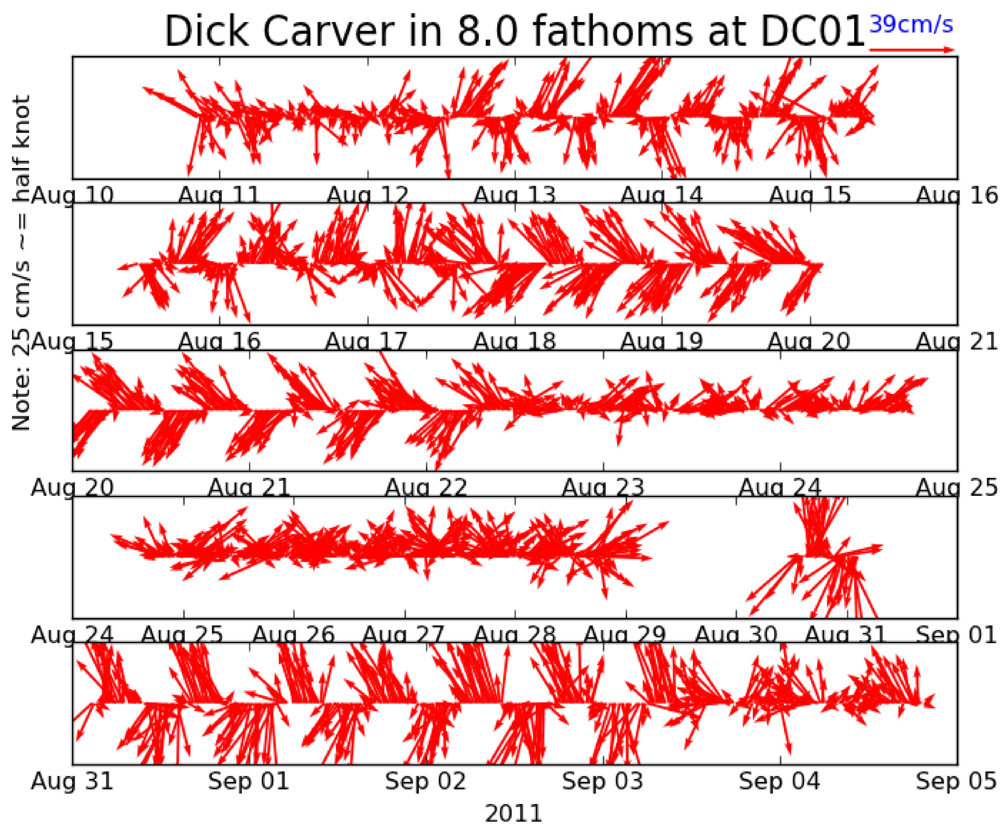


Figure 6. Example of the current meter data collected from lobster traps in 2011. The hole in the plot on 29 August is the result of Hurricane Irene causing speeds greater than the program accepted as realistic flow.

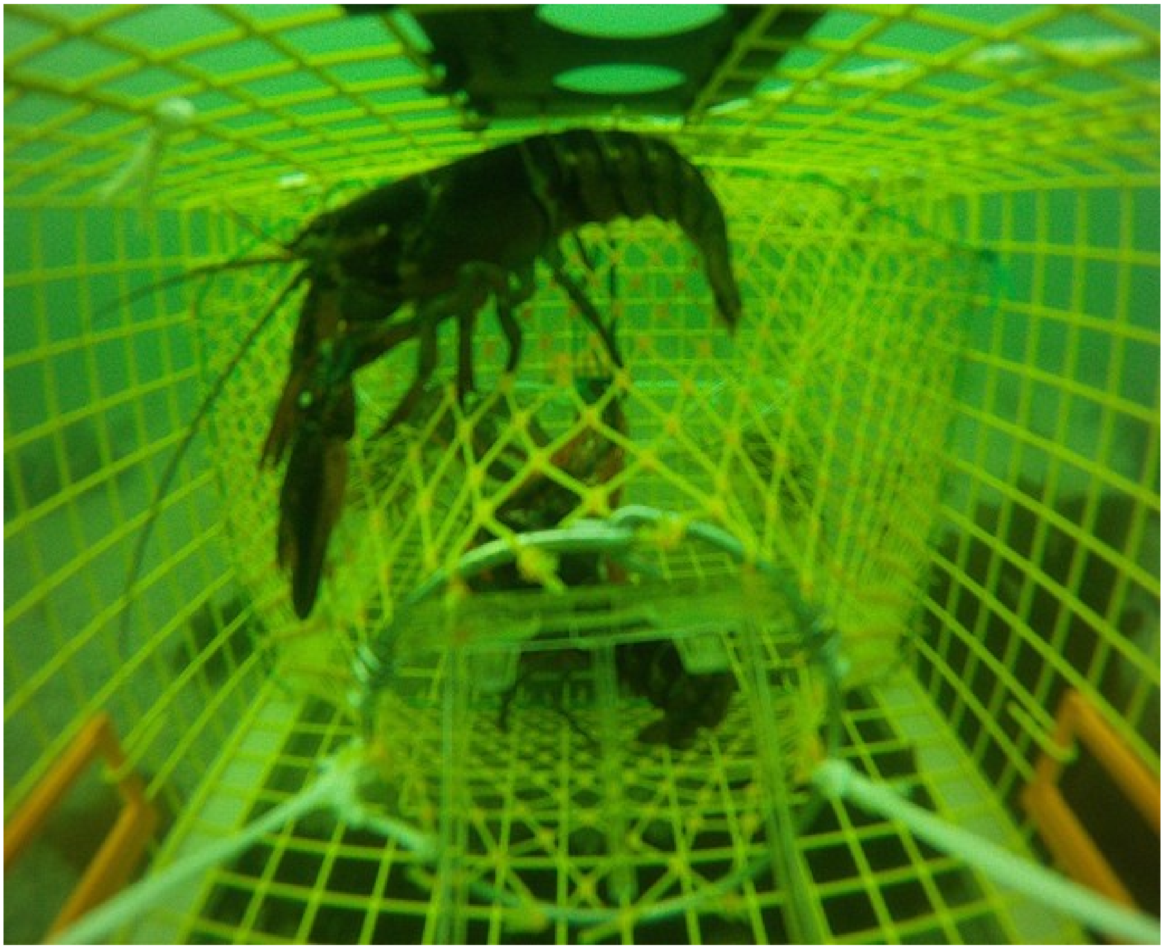


Figure 7. Example of lobster photo as archived by lobstermen. This one is by Bill Doherty in 10 fathoms outside Boston Harbor.

Results to date:

Considerable advances have been made towards the validation of local ocean models in the last few years. Given new utilities that allow investigators to remotely access a variety of web-served model output, it is now possible to examine these models without needing to bother the modeling teams that generate the output. These are powerful new tools that can be leveraged.

Because of the activity associated with this NEC-funded grant, Manning was invited to sit on a advisory panel that evaluates UMASSS Dartmouth's FVCOM model operations: the Northeast Coastal Ocean Forecast System. Much of the work that has been done and the tools that have been develop in this grant therefore have addressed the FVCOM model in particular. However, there are multiple models that simulate our coastal waters and these tools have been applied to these other models as well.

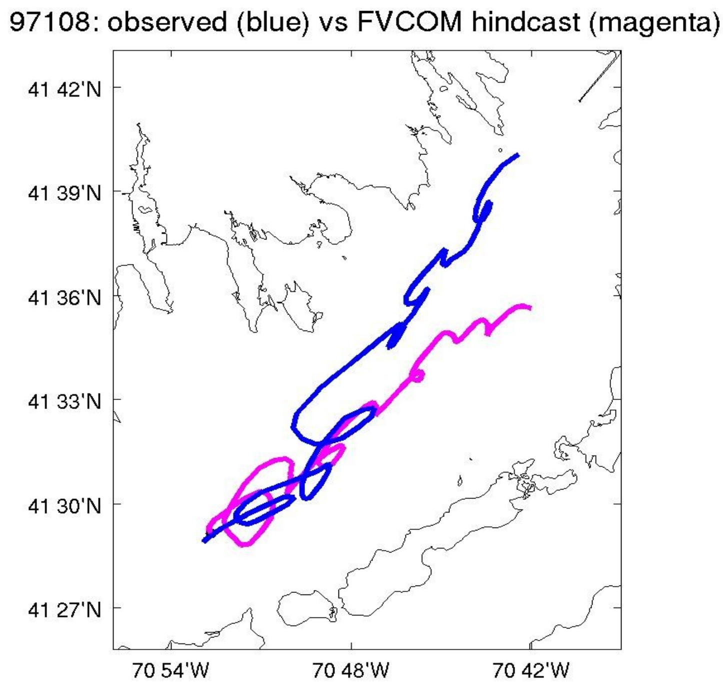


Figure 8. Example of comparing model drifter track vs observed. This case is for one drifter flowing up Buzzards Bay in July 2009 where the model captures the events but not the absolute values.

The validation of models has progressed along a few fronts associated with different data products. We compare the model output to eMOLT drifters, eMOLT bottom temperatures, and GoMOOS moored current observations. Examples of these comparisons are posted at http://www.nefsc.noaa.gov/epd/ocean/MainPage/circ/necofs_vs_eMOLT.html and are shown below in Figures 8-10. While this website is a work in progress and should NOT be linked from any public site, it provides an up-to-date summary of our efforts to date. As of this writing, most of the code has been written to make the comparisons but a quantitative analysis of the models will not be complete for several months from now and the results should appear in the final report of this grant.

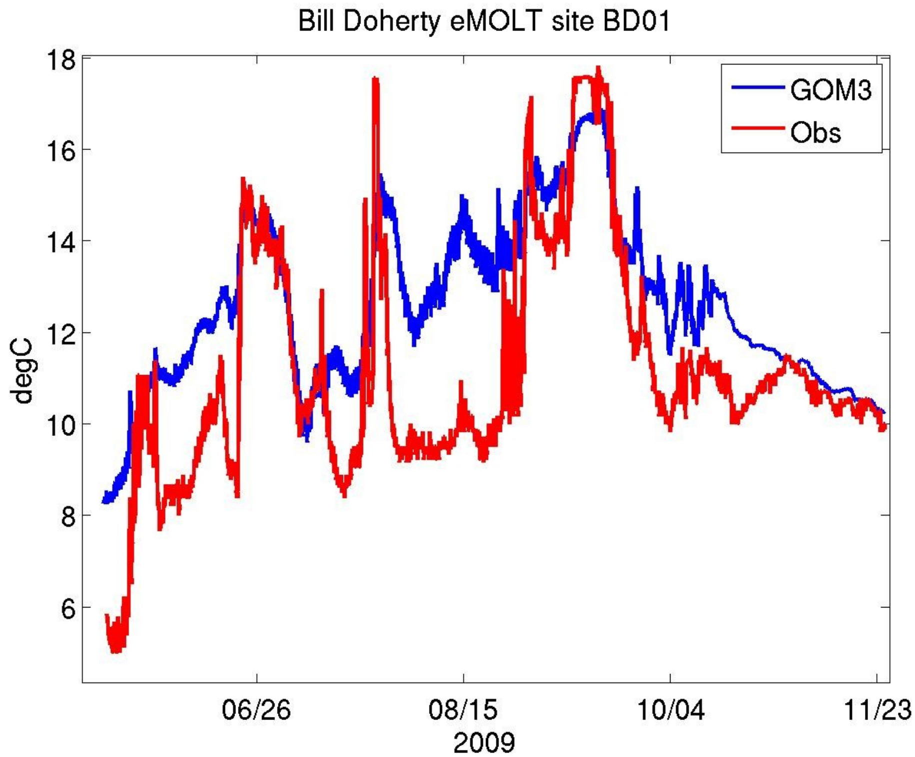
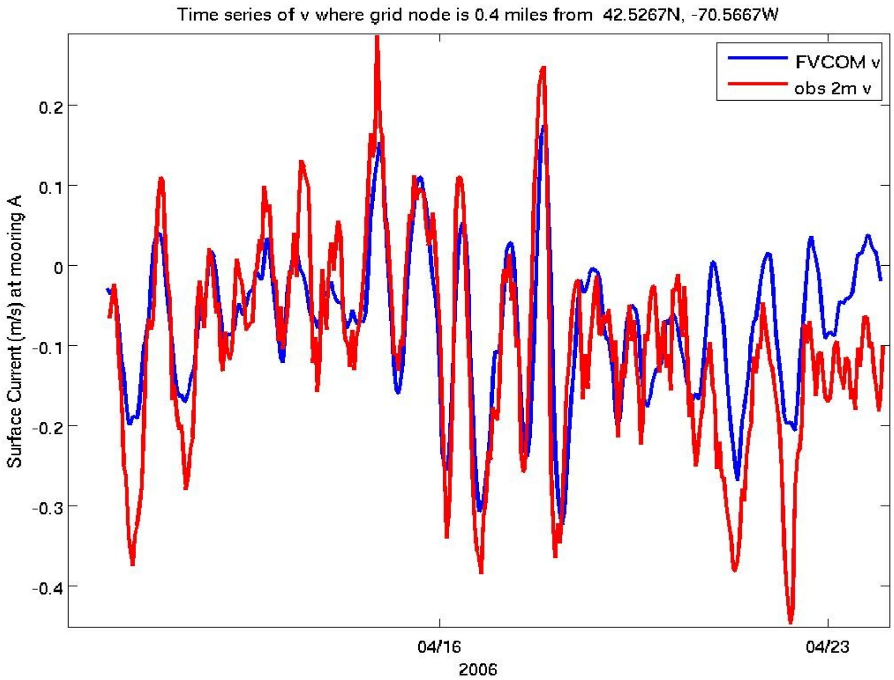


Figure 9. Example of comparing model temperatures to eMOLT bottom temperatures. This case is for Bill Doherty's site off Boston Harbor.



Figure

Figure 10. Example of comparing model to GoMOOS mooring time series of northward velocity. This case is for mooring "A" in April 2006 where the model does generally well.

Our drifter data is accessed by other groups for the purposes of validating their models. Other labs (North Carolina State, UMASS Dartmouth, and Rutgers University) have manuscripts underway that describe a model – data comparison using eMOLT data. One of the figures from NCSU study is provided in Figure 11.

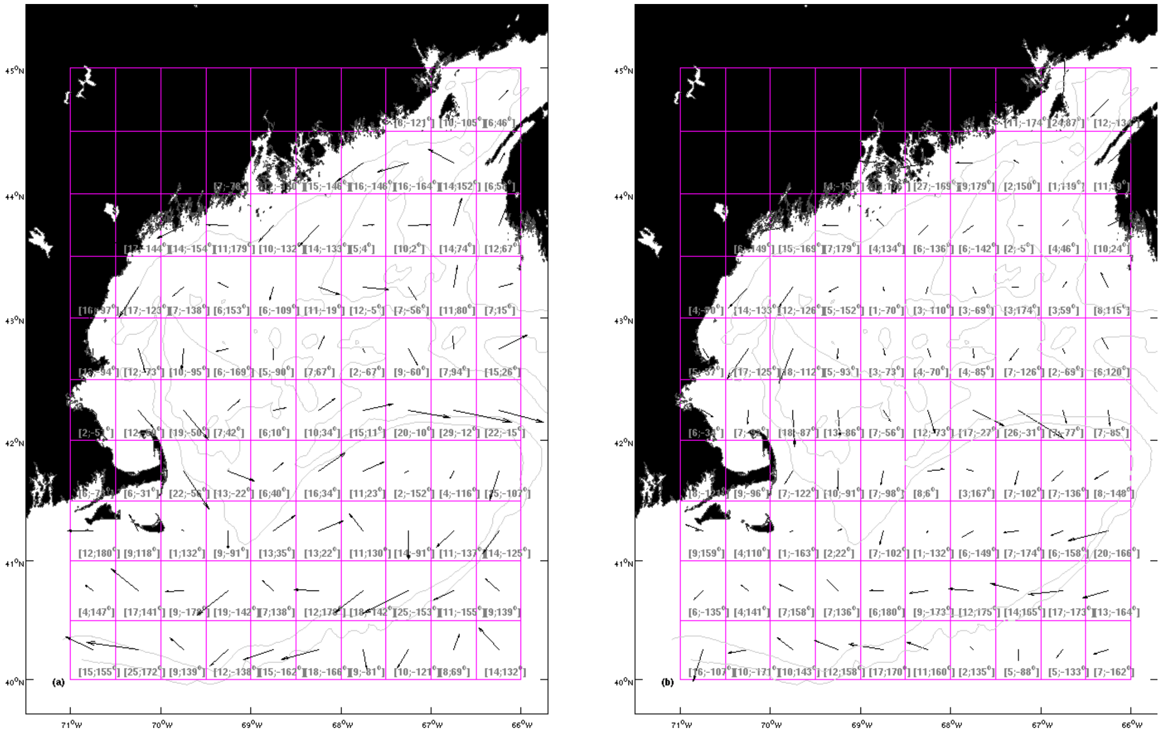


Figure 11. From: The Coastal Connectivity in the Gulf of Maine (2012) He., R, Li,Y. , J. P. Manning., to be submitted toDSR-II comparing model vs data mean flow field.

Future work:

Given that more drifters were deployed in 2011 than any previous year, it is unlikely that the drifter project, first funded by NEC in 2004, is going away. We do not expect additional seed funding from NEC but, given the results thus far, we hope to be able to secure routine operational funding from other NOAA sources such as ECOHAB or IOOS. There is also some chance we may be able to obtain funding indirectly from Ocean Observatory Initiative (OOI). There are indications that our colleagues in the Middle Atlantic Bight may be looking for drifter data for both model and CODAR validation.

In addition to more drifter deployments, we hope to continue the development of the bottom current meter. Our proposal to NOAA's Advanced Technology Working Group to add a digital compass to the instrument has been funded and will allow us to better resolve the direction of current. As noted above, we hope to also distribute more digital cameras to our lobstermen in an effort to monitor our instrument performance as well as the lobster catch activity.

We continue to make improvements to the presentation of our results on the web. The most recent additions are pages that allow teachers and students to document their deployments and enter the necessary metadata in a standardize way. There are also a variety of googlemap presentations of the tracks. The new drifter website is at: http://gisweb.wh.whoi.edu/cgi-bin/ioos/drift/driftTable.cgi

Similarly, the results associated with the new bottom-current meter is posted at: http://www.nefsc.noaa.gov/epd/ocean/MainPage/tilt/shtcm.html where there are links to all the time series data collected thus far. Web presentations will continue to evolve as new display methods become available. Flash animations, for example, are now posted and provide far more effective visualization of both modeled and observed drifter tracks.

Finally, we are waiting for the results of a proposal submitted to NOAA's Office of Aquaculture. We have asked to install our instrumentation on local oyster farms in order to investigate the relationship between current and shell growth. As part of this work, we have proposed to continue our assessment of local circulation model output.

Impacts and applications:

Hundreds of eMOLT-style drifters have been deployed over the last several years in support of the ECOHAB and GOMTOX programs to study the advection of Harmful Algal Blooms. In 2010, the GOMTOX-funded drifters revealed an unusual offshore veering of the coastal current near Casco Bay that helped explain the lack of toxic cells in the Mass Bay region that year. The realtime plots of these drifters are often watched by shellfish managers as a index of the surface water transport towards or away from their shores. In years like 2005 where there was a series of northeasterly wind events, the drifters could be seen along the coast and advecting shoreward. It was a very different situation in 2010 (Figure 12). A manuscript recently submitted (McGillicuddy et al, 2011) provides the full story of the suppression of HABs in 2010.

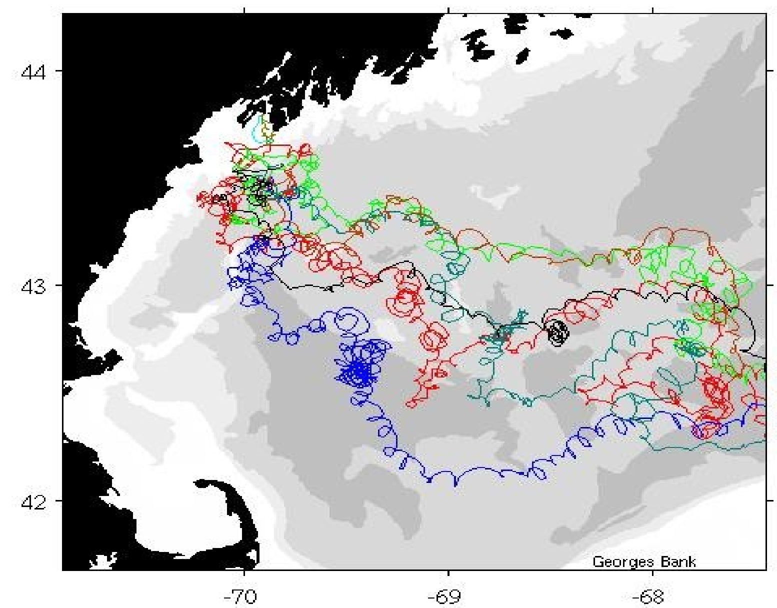


Figure 12 GOMTOX-funded drifters in 2010 tracking offshore from Casco Bay and therefore explaining the lack of toxic cells appearing in MassBay shellfish beds.

There are many other recent examples of why these models are useful. Last year, there was the question of why a sudden rise in the toxic Alexandrium cells in Nauset Inlet occurred in June 2009. We were ask to evaluate the circulation pattern of the coastal current just prior to that event to determine if there was an influx of surface waters into the inlet. The combination of modeled and observed paths (Figure 13) depicts the real possibility.

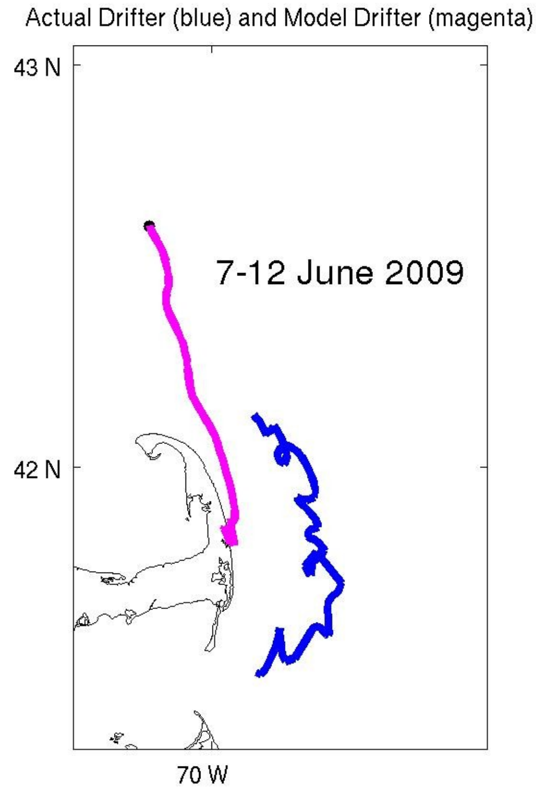


Figure 13. Trajectory of both actual and simulated drifter paths prior to the June 2009 toxic Alexandria outbreak in Nauset Inlet depicting the numerical results of a particle released in the model fields just east of Stellwagen Bank on June 7 (magenta).

This past year we were asked to simulate the path of a drifter that unfortunately lost its GPS transmissions but subsequently recorded tagged animals on the acoustic receiver that was attached to the drifter (Figure 14). The model in this case was the “simple” model as described by Manning et al 2009.

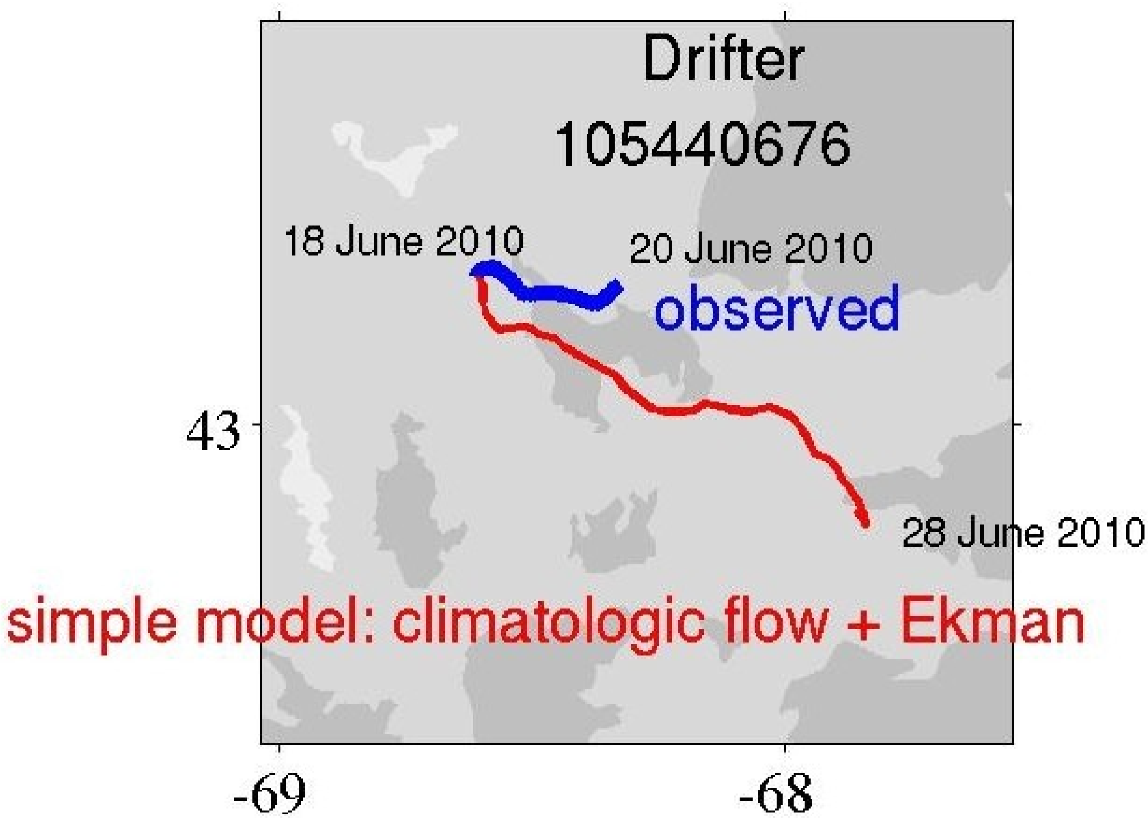


Figure 14. Trajectory of both actual (thick line) and modeled (thin red line) depicting the ESE-ward flow in late June 2010. The simple model is the result of moving a particle through empirically derived drifter climatology and adding a wind-driven Ekman component.

Very recently (March 2012), we were asked by some marine mammal researchers to estimate the track of a dead right whale. We plugged in the positions and times of the last-known sighting and simulated the trajectory using both UMAINE POM model as well as the UMASS FVCOM model to provide them with the plots posted at:
http://www.nefsc.noaa.gov/epd/ocean/MainPage/whale/mar12wb/mar12wb.html

Related projects/partnerships:

The most relevant projects are the Regional Associations of Coastal Observing Systems in both the Mid-Atlantic (MARACOOS) and the Northeast (NERACOOS). As a member of the board of directors on the former and the data management committee on the latter, Manning is actively involved with these initiatives and hopes to promote the eMOLT idea in both organizations.
The Gulf of Maine Toxicity (GOMTOX) project is also very much aligned with eMOLT objectives in the observation and modeling of ecosystem processes over multiple years. The objectives of the Northeast Coastal Ocean Forecast System (NECOFS) also runs parallel to eMOLT directions. We are beginning to

exchange ideas with the Northeast Cooperative Research Program in the last few months where, for example, we are attempting to develop a real-time probe for both mobile and fixed-gear applications. The objective is to exchange data, ideas, code, and instrumentation between all of these analogous efforts.

Presentations:

A presentation on drifter tracks was delivered at a meeting of Atlantic Salmon researchers in Portland Maine in January 2011. They are interested in the pathways of smolt transport after they enter the ocean from the rivers in Maine. As documented in Friedland et al (2011), the variability of the coastal current and its potential to change over climatic time scales may significantly affect the ability of salmon to maintain there existing population levels.

A presentation was made to the public at the South Shore Art Center in Feb 2011 where there was a show on “things in motion”. The animated drifter tracks provided an interesting discussion among those that attended.

Given this last phase of NEC funding, a full day eMOLT session at the Maine Fishermen Forum occurred on 3 March 2011. Dozens of lobstermen attended this event and were treated to a series of talks including those by Ru Morrison (head of the Northeast Regional Association of Coastal Observing Systems), Diane Cowan (Lobster Conservancy), Lew Inzce (USM lobster biologist), Paul Music (NOAA), and Heather Desse (Island Institute). Lobstermen heard first hand of the efforts underway to provide them with a real-time ocean forecast system as well as the results of the various eMOLT projects by Manning and Sheremet. This session was well attended (Figure 15) and exposed many more fishermen to our efforts to monitor and understand the environment. Another presentation was made by Manning at the March 2012 forum as well.

Figure 15. Active eMOLT participants at the March 2011 10-year anniversary get together.

A presentation was made to colleagues at the Massachusetts Division of Marine Fisheries in June 2011 illustrating the mean flow patterns that are beginning to emerge from the multiple drifter deployments this group has assisted with in the last few years.

A presentation was made to the Boston Sewage Outfall Scientific Advisory Committee in June 2011 showing the results of drifter and model tracks in Mass Bay.

A presentation was made at the National Marine Educators Annual Conference in Boston, MA on 1 July 2011. The objective is to transfer the drifter technology to teachers around the country. We shared the construction manuals, computer code, and lesson plans needed to engage students in both the hands-on activity of building and tracking of drifters.

A presentation on eMOLT was made by Manning to the ICES Working Group on North Atlantic Regional Seas in March 2012.

Published reports and papers:

Friedland, K.F., J. Manning, J. Link, A. Gilbert, and A. O'Connell. 2011. Variation in wind and piscivorous predator fields affecting the survival of Atlantic salmon, Salmo salar L., in the Gulf of Maine. Accepted by Fishereis Management and Ecology.

He., R, Li,Y. , J. P. Manning. The Coastal Connectivity in the Gulf of Maine (2012) , to be submitted to DSRII.

McGillicuddy, D.J., Jr., D.W. Townsend, R. He, B.A. Keafer, J.L. Kleindinst, Y. Li, J.P. Manning, D.G. Mountain, M.A. Thomas, D.M. Anderson. 2011. Suppression of the 2010 *Alexandrium fundyense* bloom by changes in physical, biological, and chemical properties of the Gulf of Maine. Submitted to Continental Shelf Research.

Manning, J.P., D. McGillicuddy, N. Pettigrew, J. Churchill, L. Incze, 2009, Drifter Observations of Gulf of Maine Coastal Current, Continental Shelf Research. doi:10.1016/j.csr.2008.12.008.

Data:

The eMOLT temperature, drifter, and now moored current meter data is posted at emolt.org and accessible via OPeNDAP as it has been for the last decade. Computer code is now posted on the website that allow users to by-pass the traditional point-and-click web-based methods so that they can access the data directly in from Python or Matlab environments.